Instructor Guide:
Integrating Project Leadership, Artificial Intelligence, Simulation and Google Tools to Understand Regulation of Gene Expression with the Lac Operon and Lactase Gene

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Abstract

Scientific leadership and current artificial intelligence (AI) skills are important skills to be included in the course curriculum. Together or individually, these skills can enhance knowledge, critical thinking, and creativity. In this guide, we provide an overview of how leadership skills and AI can be integrated into class activities to help students understand examples of regulating gene expression. Through the activities, students develop an understanding that genomics is an interdisciplinary, transdisciplinary and multidisciplinary field to study gene structure. Using simulations, students use the prokaryotic *lac operon* and eukaryotic *lactase* gene to learn about regulatory processes of transcription and translation. By studying the *lac operon* in bacteria and the *lactase* gene in eukaryotes, students can apply these concepts by performing independent literature searches to additional mechanisms of gene regulation. This lesson highlights the nature of central dogma of molecular biology and also provides introduction of key concepts in genomics.

Description

In this lesson students will learn concepts of gene organization, transcription, and translation. Additionally, students will apply knowledge and skills to understand, apply, and explore the role of gene expression in biological processes of both prokaryotic and eukaryotic organisms. Students will learn through lecture slides, videos, and simulations. Students will engage in learning activities to advance knowledge and attain transferable skills. Students will also participate in individual and group work taking up leadership roles, exploring simulations, and applying artificial intelligence tools to learn about gene expression.

Course Name	**Genomics**
Grade Level / Student Ages	Senior / 20
Prior Knowledge	Prior knowledge with AI, Web application and Simulations will be better
Learning Goals	Genomics: Gene Expression & Lac Operon

Materials and Technology	Project Leadership (4) will be introduced by instructors to students first and then leadership roles will be assigned by each group of students. During the group work, students will also provide feedback to each other. As students are working in groups and taking on different roles, they will be using NCBI Pubmed & Google Scholar to search for articles describing prokaryotic and eukaryotic gene expression, then download the articles, take different roles to evaluate the scientific structure of the article. In critiquing the articles, students will apply both IMRAD analysis (Introduction, Method, Results and Discussion) and the CRAP Critical Thinking Tool (Currency, Reliability, Authority, and Purpose) on a selected article. During group work, students will use Project Leadership to assign roles and give feedback to each other while completing IMRAD analysis. The groups will create the materials for a presentation of prokaryotic and eukaryotic gene expression, organize the materials, prepare the presentation, and finally deliver it during the post-implementation phase. Textbook - Students can also refer to the undergraduate biology textbook - Fundamentals of Biology by Dr Pankaj Mehrotra - https://tophat.com/catalog/science-&-math/biology/full-course/fundamentals-of-biology/3894/

Course Name	**Genomics**
	Artificial Intelligence (AI) - AI tools such as Copilot or Gemini will be used and prompts will be shared to obtain initial information and students will then also create prompts. The instructor will have example prompts to use and guide a study plan about gene expression. For example, *How do prokaryotes and eukaryotes differ in the ways that they regulate gene expression?* Course and institution policy to guide students on citation etiquette and transparency of AI usage Simulations - PhET Simulation and HHMI-Biointeractive: PhET Simulation - Gene Expression | DNA Transcription | Protein Synthesis - PhET Interactive Simulations Gene Machine: The Lac Operon - Gene Regulation | Genes | Cellular Metabolism - PhET Interactive Simulations HHMI Biointeractive - Regulation of the Lactase Gene Google Tools : Students will be using Google doc for collaborative work and also for preparation of presentation.
Estimated Time	1h:30 min for Phase I and II plus additional time for Phase II

Phase I – Pre-implementation	
Warm Up	
Instructor will	*Student will*
Inquiry Based learning- engage students in stump your partner activity i.e. ask students	TASK - Students will use the available resources like research articles (available on

to think and write a challenging question one with AI and another without AI.	NCBI Pubmed), books, AI, and science communication articles to think and search for a challenging question related to gene expression.
Exploration	
Instructor will	*Student will*
Instructors will give instructions to students to identify the components and their function of PhET Simulation gene expression, Operon and HHMI – Lactose Intolerance Click and Learn Type.	Students will explore the simulations independently and then in peer groups.
Explanation	
Instructor will	*Student will*
Instructor will help familiarize students with new terms by conducting a one-word association and one-sentence summary. For example, in the one word story –instructor will engage the whole class or a group of students and start the process by announcing a term, say, “nucleotide”, then one of the students can add another term, say “ codon”, then next student may add, “ gene” and so on. Next, instructors will select a component of the simulation and ask the student to describe its function. After all students participate in the one word story, each student will use the Google doc to either say or write a one sentence summary of any of the terms.	Students will actively engage with each other in adding words/terms first to one word story and later one sentence summary.
Phase II - Implementation Phase	
Elaboration	
Instructor will	Student will
Instructor will ask students in groups to explore the Gene Expression PhET Simulation, PhET Simulation Operon and	Students in the group will open PhET - https://phet.colorado.edu/en/simulations/gene-expression-essentials and then https://phet.colorado.edu/en/simulations/gene

click & learn type HHMI – regulation of lactase gene.	-machine-lac-operon and then then HHMI Click & Learn Type https://www.biointeractive.org/classroom-resources/regulation-lactase-gene Students will then list the components of each simulation for example biomolecular tool box on the left hand side of the simulation (positive & negative transcription factor, ribosomes, mRNA destroyer, RNA polymerase), below the biomolecular tool box - regulatory region & transcribed region and on the right hand side of the box - protein sequence.
Instructor will help students review how to identify the carbohydrates in their diet by creating a table in which they list the food they ate during breakfast, lunch and dinner. Then they will further classify the food into carbohydrates, lipids, proteins. Students can use AI or google search to classify them into carbohydrates, proteins, lipids as well. Finally they can use the same tools to identify those food items which have lactose.	Students will then get involved in real life discussion of what food they ate today and yesterday or during the last week. And which food has protein, lipids and carbohydrates. The students will create a table to list first the food they ate, then in the next table they will be able to classify the food into carbohydrates, protein and lipids and finally identify food which they had lactose using AI or Google search. Each student will create their own table to list the
Instructor will then explain how mRNA is translated to create proteins. They Then Ask students to use all the three simulations (Basic Gene Expression & Bacterial Lac Operon from PhET and HHMI-Biointeractive) to understand methods of gene regulation. One simulation helps students understand how the lac operon functions and how expression of LacZ, Lac Y and Lac A is activated. The other simulation demonstrates how lactase expression is regulated in eukaryotes to digest sugar (lactose) from lactose rich food (milk) they eat and especially lactose rich food by mode of action of lactase enzyme.	Students will then use gene expression simulationPhET Simulation - Gene Expression | DNA Transcription | Protein Synthesis - PhET Interactive Simulations first to understand how the lactase protein is formed through mRNA translation. Students will then use the second simulation on Lac Operon Gene Machine: The Lac Operon - Gene Regulation | Genes | Cellular Metabolism - PhET Interactive Simulations & HHMI-Biointeractive click & learn type - Regulation of the Lactase Gene to understand the application of gene expression in everyday life to digest lactose present in food (sugar in milk specifically lactose in milk). Students will then use click and learn type HHMI animation to analyze the gene expression in different individuals who are digesting lactose. Students in the group

Instructor will then guide students to use self-documentation tools to create evidence supporting each member's learning outcomes (see student column for specifics).	will further compare the prokaryotic and eukaryotic gene expression by taking leadership roles and then give feedback to each other through Project Leadership activities. Students will be asked individually to take a screenshot of each of three simulations when they play the simulation to show their understanding of gene expression, application of gene expression in lac operon and then importance in everyday real life examples of lactose gene expression in themselves and other individuals. Students will then annotate the screen shots.
Post - Implementation Phase III	
Evaluation	
Instructor will	*Student will*
Instructor will create a gallery walk so that students can submit their individual and group work. Instructor will then organize a mini-colloquium so that each group gets the opportunity to share their learning outcomes. For example if there were four groups then two groups present and two groups move to the group presenting to listen and ask questions. And then they move to the second group. Finally, the two groups which did not present – they get the opportunity to present and each group which presented earlier	Students will then submit their individual and group learning evidence (screenshots from simulation usage, comparison of prokaryotic and eukaryotic gene expression and IMRAD and CRAP tool analysis) to the instructor for presentation on board or power point slides to be shown on small screen television. Students present evidence of how genes are regulated by presenting their individual research. Each member of the group will present what they have learned. Students will then move to other groups to

moves around to each group to ask questions to the presenting group.	listen and ask questions.
Extension	
Instructor will	*Students will*
Instructor may give this work in classroom or out of classroom	Students can extend this activity by searching for research articles on NCBI PubMed and then discussing various future research directions related to gene expression and lactose intolerance. Students can explore regulation of genes that interest them and can research expression of different genes in different diseases.

Reference

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